approach profile and tracking are shown from 12,000 feet out from the hover pad. The ground microphone array for the noise footprint extended 8000 feet uprange from the hover pad and 1000 feet beyond. In the figure, the approach track shows the desired height-distance profile as a dashed line, with the actual position track shown as a solid line around it. Airspeed began at 70 knots. Decelerations are initiated by moving the nacelles farther aft, ultimately to the hover position of 90 degrees. Nacelle position is moved in discrete steps, beginning at 70 degrees. A small amount of full aft nacelle position (95 degrees) was used for braking just before coming to a hover over the landing pad. Careful control of the aircraft flight condition as conveyed to the pilot by the flight director results in the concentration of approach noise in the immediate environs of the landing pad while minimizing noise along the approach track.

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Methods for Predicting Blade-Vortex Interaction Noise

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Rotor-vortex interactions have been the subject of many experimental, analytical, and computational studies. Most of this activity is motivated by the importance of blade–vortex interactions (BVIs) as a major source of rotorcraft noise and vibration problems. The conceptual simplicity of the problem has encouraged the development of numerous computational methods, ranging from simple, incompressible two-dimensional analyses to full three-dimensional Euler/Navier–Stokes computational fluid dynamics (CFD) codes. However, experimental data of comparable simplicity were unavailable because of the difficulty of generating sufficiently clean vortices in a wind tunnel environment, and also because of the difficulty of acquiring corresponding loading and acoustic data. These experimental problems have been largely solved by the rotor/vortex-generator approach originally employed by B. McCormick (Pennsylvania State University) and later developed into a full aeroacoustic test at Ames Research Center. The first figure shows the rotor and vortex generator in the Ames wind tunnel setup.

Fig. 1. Parallel BVI experiment in the Ames 80- by 120-Foot Wind Tunnel.

The data obtained from this test were suitable for evaluating computational models and became the focal point for an extensive correlation study. A wide range of participants from industry, academia, and government, both in the United States and abroad, contributed to the study. The results were collated by an ad hoc working group.

The study considered two simple parallel BVI interactions, a near-miss case and (to a more limited extent) a direct-hit case, and determined that the pressure and acoustic data (together with the inferred vortex model) are a suitable basis for the initial validation of computational models. A user of these data should expect to first obtain reasonable comparisons with these blade-surface and acoustic data before proceeding on to compute more complex interactions.

Overall, excellent results were obtained, indicating that a significant capability exists to predict the BVI interaction and its acoustic implications. Representative acoustic results are illustrated in the second figure. This does not imply, however, that the acoustic problem is solved. In this test the vortex location was well known and the vortex structure was fairly well defined. In a full rotor computation, however, these inputs are not known to a great degree of accuracy, and the ability to predict them is probably the greatest challenge for the future.

One of the most interesting results demonstrated that the simplest methods worked quite well compared with far more complex models. Of course, the BVI configuration under study is intrinsically simple and only acoustic applications are being considered.

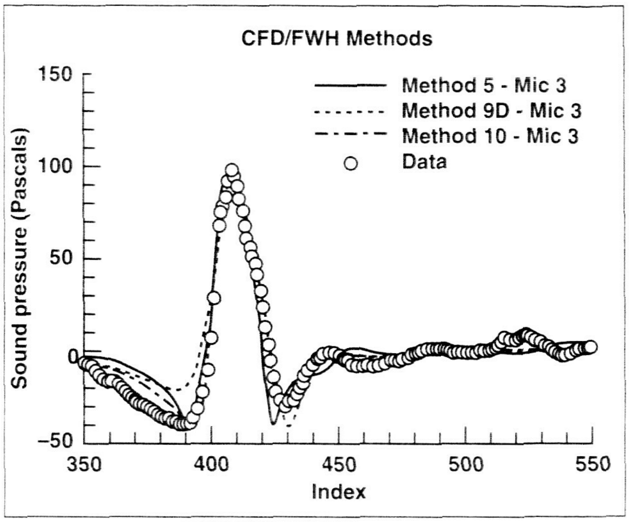

Fig. 2. Comparison of CFD/Ffowcs-Williams Hawkings methods for far-field noise with data for a near-miss parallel BVI.

Full rotor-wake computations, wherein loads and performance must be predicted (in addition to acoustics), cannot be expected to yield so easily to the simplest approaches. Nevertheless, for particular, well-understood solution requirements, it is clear that great simplifications can be made.

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